METHOD FOR PRODUCING UNIQUE AND HIGHLY CONTOURED WALL PANELS

Field of the Invention

This document concerns an invention relating generally to the production of panels for decoratively finishing walls, and more specifically to methods for producing decorative wall panels which can each have a unique and customized appearance without the need to retool between the production of different panels

Background of the Invention

In environments such as the lobbies and halls of commercial and government buildings, walls are often given a decorative appearance by installing contoured panels. These are sometimes fashioned from plain boards which are covered with fabric; in other instances, they may be fashioned from a series of decorative tiles which are similar to contoured ceiling tiles. Often, such contoured panels are installed not only for their decorative appearance, but also because their contours help to dampen echoes and thereby decrease ambient noise. Tile-like panels are often favored because they can usually provide a greater degree and variety of texture than a fabric-covered panel. Such tile-like panels are generally formed in the same manner as conventional ceiling tiles, with cementitious or other moldable material being cast into a desired shape, and/or with metal or plastic sheets being stamped into desired forms. With high-quality production processes, the panels can be quite beautiful, and when observed individually, each has the appearance of a high-quality work of art.

However, one drawback of these panels and their production methods is that they usually cannot provide significant variety in their appearance, particularly where large areas are to be covered with panels: because of costs, only a limited number of molds

or stamps are produced, and thus a limited number of panel patterns/contours are produced. Thus, when the panels are hung, their patterns will eventually begin to repeat. This has the effect of diminishing the decorative effect of the panels, since they begin to become indistinguishable to observers. Additionally, their impact as artwork is greatly diminished: since they repeat, they convey the impression of being mass-produced, which detracts from their artistic feel. It would therefore be useful to have available methods of producing panels which reduce or eliminate these drawbacks.

Brief Description of the Drawings

FIG. 1 schematically illustrates an exemplary panel **100** which may be produced in accordance with the methods of the invention, with the panel being cut by a computer-driven cutting head **12** from a board **102** (the original shape of which is illustrated in phantom).

Detailed Description of Preferred Versions of the Invention

The invention involves a panel production method which is intended to at least partially solve the aforementioned problems, and allow the relatively rapid and inexpensive production of wall panels which are each unique, or which at least may have a low tendency for pattern repeats, and/or which might be granted a highly "organic" and appealing appearance owing to the introduction of deviations in repeating patterns and/or owing to the presence of contours which are not attainable via conventional stamping and casting processes. The invention is further intended to allow the rapid and inexpensive reconfiguration of the panel production tooling to produce panels having different designs without the need to produce new molds, stamping dies, or make other significant capital expenditures. So that the reader may attain a better understanding of the invention, which is defined by the claims set forth at the end of this document, following is a detailed description of preferred forms of the invention.

To produce panels in accordance with the invention, a user must first choose the material from which one or more wall panels are to be manufactured. As will be discussed below, the panels are preferably manufactured using computer-controlled machining tools such as saws and routers, though other forms of computer-controlled machining may be possible as well. Since CNC (computer numeric control) routers and the like require a machinable substance to work on – one which will not chip or break as a cutting head moves across its surface and removes material – particularly preferred materials for panel manufacturing include boards made of solid wood, medium density fiberboard (MDF), or calcium silicate (which is known for its fire-resistant properties). However, other machinable materials (e.g., plastic boards, metal slabs) are also possible material choices. It is also possible to apply the panel formation process described below to a slab or bed of soft/unfired ceramic material, which may then be fired or otherwise set to generate a finished panel.

A board of the chosen material – depicted in phantom at **102** in **FIG. 1** – is then affixed to the tool bed (as by the use of fasteners, clamping, and/or by vacuum pressure) of a CNC machine tool or other computer-controlled cutting apparatus. In **FIG. 1**, such a tool bed is designated at **10**. In common CNC machine tools, the cutting head – e.g., a saw blade rotating about a horizontal axis, or a rotary cutting head rotating about a vertical axis (as depicted at **12**) – is driven about a horizontally-oriented XY plane across a board **102** or other substrate mounted on the CNC tool bed **10**, with the tip or bottom edge **14** of the cutting head **12** having its position in the Z direction adjusted during such motion. Usually, motion between desired XYZ locations is achieved by moving between discrete XYZ points defined in a pointset generated by a CAD model of the desired endproduct: the surfaces of the CAD model are discretized into individual points representing the surfaces of the endproduct, and then the cutting head **12** moves between these points, generally by sequentially moving along lines of constant X (and varying Y and Z) or constant Y (and varying X and Z). Thus, the board **102** or substrate is shaped

into the endproduct in multiple cutting passes. Motion of the cutting head **12** versus the tool bed **10** may be achieved in a variety of different ways, as by situating the board **102** on a stationary tool bed **10** and actuating the cutting head **12** to move in the X, Y, and Z directions; alternatively, the cutting head **12** may be held stationary and the tool bed **10** (and the board **102** affixed thereon) may be moved in the XYZ directions, or a combination of cutting head **12** and tool bed **10** motion can be used.

In the present invention, rather than using human design talent to generate a complete panel design, render this design using CAD processes, and then cutting a board **102** to produce the panel **100** in accordance with the CAD design, panels **100** are designed and cut from boards **102** in accordance with a mathematical formula which defines a surface in the XYZ domain. The mathematical formula may take a variety of forms, such as a simple polynomial equation, trigonometric function (also called circular functions, i.e., a function including one or more of sines, cosines, tangents, cotangents, secants, or cosecants of values, or the inverses of these functions), or other function (or a combination of the foregoing) which is normalized or otherwise rescaled so that the surface defined by the formula rests within the space defined by the board **102**. As an example, where the board **102** illustrated in **FIG. 1** is regarded as having an X width dimension bounded by opposing right and left surfaces **104** and **106**, a Y height dimension bounded by opposing top and bottom surfaces **108** and **110** (deemed a "height" dimension since it will extend vertically when the panel **100** is mounted on a wall), and a Z depth dimension bounded by opposing front and rear surfaces **112** and **114**, the illustrated panel **100** has a surface defined by the following equation:

$$z = \sin(b * Y + 6 * \{\sin[a * (X + 5) + .1 * \sin(b * Y) + .3 * \sin(c * Y)]\}) + \sin(b * Y + 6 * \{\sin[a * X + .3 * \sin(b * Y) + 0.1 * \sin(c * Y)]\})$$

wherein

$$a = (2 * pi) / 24$$

$$b = (4 * pi) / 24$$

$$c = (12 * pi) / 24$$

And wherein z is rescaled to the depth value Z to fit within the boundaries of the illustrated board **102** by adjusting it in accordance with:

$$Z = z / 9.76 - 0.305$$

It should be understood that the foregoing mathematical formula is merely exemplary, and a wide variety of other formulae may be used instead, leading to panels **100** having differently-contoured surfaces. The formulae may vary in complexity, and may incorporate features such as random number generators to constantly or periodically vary the contour (Z depth) of the panel **100** over the XY plane, or they could incorporate conditional statements which change formulae and/or their features when some predefined condition is met. As an example, a formula may be defined and then applied to a panel **100** without first rescaling the formula to fit within the boundaries of the board **102**, and a conditional statement might then be applied whereby if the Z depth value is outside the Z depth of the board **102** for a given XY value (i.e., if it does not touch the top surface **108** of the board **102**, or if it penetrates or grows undesirably near the bottom surface **110** of the board **102**), the Z value is divided by some value which rescales it to fit within the boundaries of the board **102** (with this divisor being incremented, decremented, or otherwise changed if it is initially insufficient to place the Z value within the board **102**). The use of random number generators and/or conditional statements is appealing because in some cases it can generate a sudden and significant change in the appearance of a board owing to an alteration in the fundamental underlying formulae. To illustrate, a conditional statement might generate a new contour pattern over regions of a formula which have Z depths resting outside board boundaries, or a randon number generator might periodically change the appearance of the panel (or might randonly alter the nature of the surface formula once a conditional statement is triggered).

Once the mathematical formula is defined and a board **102** of the chosen panel material is affixed to the tool bed **10**, the cutting head **12** and/or tool bed **10** are driven

relative to each other so that the cutting head **12** is driven across the board **100** in accordance with the mathematical formula to cut the front surface **112** of the board **100**, giving the board **100** a contour reflecting the calculated Z values over the X and Y dimensions of the board **100**. While it can be possible to generate Z values (and drive the cutting head **12** and/or tool bed **10**) "on the fly" (e.g., by simply incrementing X and/or Y values, calculating corresponding Z values, and then moving the cutting head **12** and/or tool bed **10** accordingly), the programming of some CNC tools must be significantly modified to implement such "on the fly" calculation. Therefore, it is preferred to generate a board pointset before beginning cutting, with the pointset being generated by discretizing the X and Y dimensions of the board **102** – e.g., by determining XY points evenly arrayed at discrete space increments across the board **102** (such as at every 0.1 inch across the dimensions of the board **102**) – and then calculating all Z depth values at these XY points. In this manner, the CNC tool can simply move the cutting head **12** and/or tool bed **10** from point to point in the pointset until the entire surface of the panel **100** has been cut into the board **102**. For example, the CNC tool might first place the cutting head **12** at the point that has the lowest X and Y values (adjacent the left and bottom surfaces **106** and **110**), and might then drive the cutting head **12** along lines of constant Y height and increasing X width, with the Z depth varying accordingly, until the right surface **104** of the board **102** is reached. The cutting tool might then increment the cutting head **12** to the next row of points along the Y height dimension and run along the line of decreasing X width to the defined Z depths until the left surface **106** is again reached. The panel **100** may be completed by making multiple tool passes in this manner until the entire top surface **108** of the board **102** is cut.

If the panel **102** is cut via motion between points in a board pointset, it is useful to define the path of motion between the points. A simple linear path from point to point could be used; however, if the spacing of the XY points in the pointset is relatively coarse (i.e., if the XY points rest more distantly from each other), this can lead to panels

100 which have a faceted appearance. So that the panels **100** have a less machine-made and more "organic" appearance, it is preferred that the path of travel between adjacent points in the pointset be defined as an arcuate path, e.g., as an arc of a circle having some predetermined radius, or by moving along a path defined by a quadratic polynomial or cubic polynomial defined between a point and its prior and/or subsequent points, rather than by simple linear interpolation between points.

Subsequent panels **100** may then be produced by repeating the foregoing process. It is easily possible to generate a second panel for placement adjacent to the first panel, and which is contoured to extend the surface function of the first panel such that the second panel has a continuously matching edge with the first panel at the juncture between the two panels (i.e., such that the Z depths of the panels are matched at the locations where their right and left surfaces abut, along all values of the heights of the first and second panels). This can be done by simply generating a second board pointset having X width and Y height values which are adjacent to (but which have no or minor overlap with) the X width and Y height values chosen for the first board pointset. In other words, the second board is cut with a pointset which simply continues to represent the defined mathematical formula at a section of the XY plane adjacent to the section containing the first board pointset (and defining the first panel). It should be appreciated that this approach can allow continuity in the patterns of abutting panels having any shapes or sizes, and/or any form of abutting relationship (e.g., with panels being situated side-by-side, but with staggered bottom surfaces) by simply defining the pointsets for the panels over the appropriate sections of the XY plane. It should also be appreciated that the use of mathematical formulae to define and form panels, as opposed to the use of molds or stamping dyes, allows for far more rapid and inexpensive retooling when a change in panel patterns is desired.

Once a panel **100** has been cut, a decorative and/or protective finish, such as a stain, paint, or lacquer, may be provided on its cut front surface **112** if desired. The

panel **100** may then be installed on a wall in a conventional manner (e.g., by fasteners, attachment brackets, and/or construction mastic). Any adjacent panels (if used) may similarly be installed in abutment with, or spaced from, prior panels.

It should be understood that the foregoing discussion merely involves a particularly preferred version of the invention, and the invention may take other forms. The invention is not intended to be limited to the preferred version of the invention described above, but rather is intended to be limited only by the claims set out below. Thus, the invention encompasses all different versions that fall literally or equivalently within the scope of these claims.